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SHORT COMMUNICATION

Effect of tree-age on calorific value and other fuel properties of Eucalyptus hybrid

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Abstract: For determining the effect of tree-age on the fuel properties of *Eucalyptus* hybrid, the variability in basic density, calorific value, proximate and ultimate parameters of 2–6 years old trees and mature trees (20-year-old), grown under short rotation forestry regime, were measured and analyzed. Results show that there was no significant variation in the basic density of wood for 2–6 year-old *Eucalyptus* hybrid, with average value of 0.55–0.58 g·cm^{-3}; the calorific value of mature trees was higher than that of lower age trees, but the ash content was much higher in lower age trees compared to mature trees. No particular trend was observed for volatile matter content and the fixed carbon content with tree-age. In conclusion, the fuel properties of mature tree were marginally better than trees of lower age.

Keywords: Calorific value; *Eucalyptus* hybrid; fuel properties

Introduction

Biomass is the most common form of renewable energy sources. It is estimated that of the total domestic fuel wood needs, around 70% in the rural area and 35% in the urban areas are being met from fuel wood (Rai and Chakrabarti 1996). Biomass fuel has advantages over fossil fuel due to environmental concerns. The biomass fuels do not contribute to the carbon dioxide levels of atmosphere, thus, it can prevent aggravation from global warming (Ravindranath and Hall 1996). Due to strict environmental regulations and policies aiming to protect native forests, there is hardly any supply of fuel wood from the forest. This has necessitated the raising of suitable fast growing tree species for energy purpose. Such species can provide reliable long-term wood supplies as a raw material for modern conversion devices (Varma and Basant 2003). The understanding of fuel properties i.e., calorific value, ash content, volatile content, fixed carbon content, ultimate carbon and hydrogen is very important for utilization of any material as fuel (Nordin 1994; Dikinson and Kirkpatrick 1985). In the present study, we investigated the fuel properties of young trees (2–6 years old) and mature trees (20 years old) of *Eucalyptus* hybrid, with an aim to optimize the harvesting age of tree species for optimum energy conversion.

Materials and methods

E. hybrid trees of different age groups ranging from 2 to 6 years and mature trees (20 years) were procured from the Mandya district of Karnataka, India. The trees obtained for these experiments were grown under the similar soil and climatic conditions. Stump diameter (0.15 m above the ground), diameter at breast height (DBH) positions and the tree height were measured before harvesting. For each age group, 25–30 trees were measured the stump diameter, DBH and tree height, and then four trees were selected and harvested for determining fuel properties. The average values of DBH and tree height of different age group trees are presented in Table 1. Wood samples (discs) were obtained from three different tree positions (stump height, DBH and top portion with 20mm diameter) (Senelwa and Sims 1999). Twigs and branches were excluded, not taken for analysis. For a two-year old tree, wood samples were collected at three different positions i.e., 0.15 m, middle and top for different analysis. Stem disc samples were debarked and oven-dried to constant weight at 80°C. The oven-dried samples were chipped, hammer-milled and powdered to pass – 40+60 mesh sieve and further analyzed for fuel properties (Kataki and Konwrer 2001) The fuel properties were determined for each tree by taking average of their values obtained at different portions i.e., stump height, DBH and top portion. The values given in Table 1 are corresponding to average value of four trees corresponding to each age group.

Basic densities of freshly cut water-saturated samples were determined by mercury displacement volume method (Walker et al. 1993). One-gram wood powder was pelleted, oven dried to con-

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stant weight at 80°C and burned in an oxygen bomb calorimeter (LECO AC-350) for determining calorific value. The ash content and volatile matter content (dry basis) were determined using ASTM D5142 with a proximate analyzer (LECO TGA-701). The Elemental analysis (ultimate carbon, hydrogen, nitrogen and sulphur) was carried out using a CHN analyzer (LECO CHN-2000). Fixed carbon content (FCC %) was calculated from the equation - FCC (%) = 100 - (% Ash content + % Volatile matter content) .

Results and discussion

The basic density, calorific value and the data obtained from proximate analysis of *Eucalyptus* hybrid trees harvested at different ages are summarized in Table 1. The species with higher wood density are preferred as fuel because of their high energy content per unit volume and their slow burning property (Singh and Khanduja 1984; Goel and Behl 1996). The basic density of lower age (2–6 years) wood ranged from 0.556 to 0.581 g/cm^3. Basic density of mature trees (0.730 gm/cm^3) was higher than lower age group trees.

The fuel quality reduces with the amount of ash present in the biomass. The higher amount of ash in biomass makes it less desirable as fuel (Shafizadeh 1981). The amount of ash was higher in lower age trees. The low and minimum variability in ash content of wood (Table 1) indicates that ash content may not be an appropriate criterion for determining the harvesting age of tree.

Table 1. The influence of harvesting age on basic density, calorific value and proximate analysis of E. hybrid.

Tree age	Average DBH (cm)	Average Height (m)	BD (g/cm^3)	Ash (wt%)	VMC (wt%)	FCC (wt%)	CV (MJ/kg)
2 Year	3	2.5	0.564 (±0.04)	1.09 (±0.04)	81.15 (±0.08)	17.76	19.10 (±0.04)
3 Year	3.5	4.3	0.581 (±0.03)	0.63 (±0.01)	82.25 (±0.07)	17.12	19.22 (±0.04)
4 Year	4.8	6	0.549 (±0.02)	0.79 (±0.02)	82.00 (±0.08)	17.21	19.25 (± 0.04)
5 Year	5.4	7.6	0.556 (± 0.04)	0.68 (±0.04)	82.25 (±0.09)	17.07	19.34 (±0.04)
6 Year	6.5	6.9	0.575 (±0.05)	0.59 (±0.04)	81.64 (±0.05)	17.76	19.50 (±0.04)
20 Year	27.2	30.6	0.730 (±0.01)	0.43 (±0.05)	79.29 (±0.09)	20.36	20.16 (±0.04)

VMC- volatile matter content; FCC- fixed carbon content; CV- calorific value; BD - basic density. Values given in brackets represent standard deviation

The quality of fuel is known by the amount of heat (energy) generated from a unit mass of fuel (MJ/kg). The calorific value is one of the important parameters for differentiating one fuel from others. The calorific value of biomass is dependent on its chemical composition i.e., cellulose, hemicellulose, lignin, extractives and ash forming minerals (Shafizadeh 1981). Lignin and extractives have lower degree of oxidation and considerably higher heat of combustion in comparison with cellulose and hemicellulose (Kumar et al. 1992). The tree-age variability in calorific value of *Eucalyptus* hybrid trees was found to be practically marginal. The calorific value of mature tree (20.16 MJ/kg) was higher than that of lower age group trees (19.10–19.50 MJ/kg). This can be attributed to lower ash content and high fixed carbon content in the mature trees.

The results presented in Table 1 indicate that volatile matter content does not vary much with harvesting age. The fixed carbon content ranges from 17.07 to 17.76 % (Table 1), which is close to the fixed carbon content of many tree species (Senelwa and Sims 1999). During the combustion process, when the biomass is heated, the volatiles escape first and burn in gaseous state leaving behind the fixed carbon as char, which burns later in solid state. High fixed carbon content adds to high-energy value of plant material (Kumar et al. 1992). The fixed carbon content of mature tree was 20.36%, which in general is higher than that of lower age trees.

Elemental analysis results, presented in Table 2, clearly show that there is not much variation in the elemental composition among trees of different ages. The low variability in the elemental composition of different ages is responsible for low variability in the heating value of trees. The amount of ultimate carbon was found to be about 46% across the age. In any fuel, carbon-oxygen and carbon-hydrogen bonds contain lower energy than carbon-carbon bonds. Higher proportion of oxygen and hydrogen in biomass reduces the energy value of fuel (Nordin 1994). The lower percentage of nitrogen and sulphur in species is important in the view of environmental point.

Results presented in this study show that the basic density of wood increased significantly in mature trees compared with that in lower age trees. Similarly an increase in the calorific value was observed in mature trees (20 years) compared with lower age trees (2–6 years). Lemenih and Bekele (2004) reported a weak and negative correlation between calorific value and age of trees between 11 and 21 years. The lower calorific value observed in the work in lower age trees can be attributed to high ash content.

Table 2. Elemental analysis of *Eucalyptus* hybrid

Tree age	Carbon (wt%)	Hydrogen (wt%)	Nitrogen (wt%)	Sulphur (wt%)
2 years	46.95 (± 0.04)	5.61 (± 0.02)	0.14 (± 0.01)	0.05 (± 0.01)
3 years	46.90 (± 0.02)	5.70 (± 0.01)	0.16 (± 0.01)	0.06 (± 0.01)
4 years	46.23 (± 0.01)	5.89 (± 0.02)	0.14 (± 0.02)	0.05 (± 0.01)
5 years	46.09 (± 0.03)	5.95 (± 0.03)	0.12 (± 0.02)	0.05 (± 0.02)
6 years	46.11 (± 0.04)	5.56 (± 0.01)	0.16 (± 0.03)	0.06 (± 0.01)
20 years	46.81 (± 0.04)	5.87 (± 0.01)	0.16 (± 0.01)	0.06 (± 0.01)

Values in brackets represent standard deviation

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